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Manned Systems Utilization Analysis (Study 2.1)

Space Servicing Pilot Program Study

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Advanced Mission Analysis Directorate
Advanced Orbital Systems Division

30 January 1975

Prepared for OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

Contract No. NASW-2727

Systems Engineering Operations
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ACKNOWLEDGMENTS

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Within The Aerospace Corporation, support was also provided by Mr. B. Moss of the Launch Vehicles Directorate and Dr. J. Stevens of the STP Program Office. The majority of the analysis effort was performed by Mr. L. Stricker, with computer support by Mr. S. Wray and the design integration task was very ably performed by Mr. T. Trafton.

FOREWORD

This report has been prepared in response to an action item issued Sept. 1974 by NASA Headquarters, MTE, requesting information on a proposed joint USAF/NASA space servicing flight test demonstration of automated payloads. This report develops the economic benefits of such a concept when applied to the broad spectrum of future NASA and domestic payload opportunities as a basis for emphasizing the need for immediate action. The concept of space servicing is extended from automated payloads to space based operations which eventually lead to manned maintenance activities in geostationary orbit.

This provides the background for developing an overall plan for a space servicing pilot program as the first step of an evolutionary process to achieve operational capability when the full capability Tug becomes operational. Several options, employing for the most part existing flight hardware, are discussed and associated program costs are developed.

This effort has been performed as a part of Study 2.1, Manned System Utilization Analysis, one of five studies currently in process at The Aerospace Corporation under NASA contract NASW 2727. The NASA Study Director is Mr. V. N. Huff, NASA Headquarters, Code MTE.

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SUMMARY

The concept of space servicing of automated payloads offers the potential for substantial cost benefits for future payload operations. Moreover, space servicing of automated payloads, especially in geostationary orbit, provides the impetus to begin an evolutionary process that will expand the horizons of future space operations, leading to space assembly, space basing, and manned maintenance operations. But developing a new operational concept is a difficult task under most circumstances, and under tight budgetary constraints, it is nearly impossible. The uncertainty in cost estimates, the risk of changing design techniques, and the operational uncertainties all militate against change. However, the results of this study, as well as associated study efforts, strongly suggest that this process of change should be initiated now to assure continued growth of Shuttle applications in the future.

The results provided in this report indicate conservatively, that over $200 million can be saved over an 11-yr period by employing space servicing. Further optimization of the designs and operational procedures should provide even further benefits. These savings, therefore, can be used to balance the developmental costs required to achieve this capability. Although no firm estimate of DDT&E costs can be made, it is apparent that even these conservative returns will be sufficient to justify the effort.

Experience has shown, however, that any major change of course such as this must be an evolutionary process, allowing confidence in the concept to be developed prior to a full commitment of efforts. Payload programs will not automatically accept a new operational concept. The economic benefits must be proven and applied against the anticipated risk that is inherent in any new process. One approach to accomplish this objective is through a flight test demonstration effort involving payload users to overcome the inertia involved with current practices. Such a program must also provide the first step to broader applications and assure

that the initial investment has a relatively high change of subsequent benefits.

A program plan is presented which accomplishes these objectives with a relatively low investment. Two options are developed which have application to both NASA and USAF future program efforts and, therefore, through shared funding provide a capability which probably could not be achieved otherwise. Although specific design approaches are shown, it is not the intent to specify a preferred approach at this point in time because incorporation of alternate test objectives could impact the final selection. It is important to note, however, that existing equipment can be employed to a very large extent, minimizing the risk of new developmental items. It is also important to recognize that this program has the potential to evolve directly into an interim servicing capability, providing not only fundamental design and operational requirements but also hardware elements.

The total effort is estimated to cost approximately $25 million shared by NASA and the USAF. Full commitment to these funds is not required until firm design approaches and cost data are available from contractor efforts. An initial effort is recommended in the last half of FY 75 to establish mission requirements and design specifications and to develop the procurement package for FY 76. The funding levels for FY 76 require approximately $2 million each from NASA and the USAF. However, only about one-half of this is required to reach the critical design review (CDR) on all development items. At that point in time, the design will be firm, the interface specifications will be firm, and firm costing can be committed. The decision can then be made to proceed or reprogram as necessary. Hence, the commitment up to this time is little more than the current study efforts investigating various space servicing concepts.

Experience has shown that study results alone may not alter the course of current payload program efforts. Operational procedures must be demonstrated and the associated risk of development must be overcome. The Pilot Program recommended serves as a first step in developing this confidence in a new operational concept which should provide benefits to the payload user as well as to the Space Transportation System.

1. INTRODUCTION

The concept of space servicing of automated payloads offers the potential for substantial cost benefits for future payload operations. However, as with any new operational concept, there is always a risk associated with changing the normal mode of business. Assessing the risk against potential benefits is a task which often is not quantifiable, and is, therefore, referred to the judgment of top management. It is, therefore, desirable to provide as much background information on the subject as possible to assure that a management decision is made in the light of all pertinent viewpoints. That is the purpose of this report relative to space servicing in general, and a pilot flight test program in particular.

This report provides the background information leading to the recommendation for an early flight test to demonstrate space servicing. It also provides an overall program plan, building upon the pilot program, through an interim servicing capability to arrive at a multi-payload servicing concept at the time the full capability Tug becomes operational. This process is evolutionary and necessarily follows two parallel paths: as the servicing concept evolves, so must the payload user community evolve to serviceable designs. If payload designers are slow to alter their course, the benefits of space servicing, both to the payload and to Shuttle operations, will be delayed because a mature servicing concept (servicer design) can not be developed without intimate cooperation of the payload community. The inherent inertia in altering any substantial course of action such as this will more than likely result in two and perhaps three generations of servicing designs before a mature concept is achieved. This evolutionary process must be initiated in the very near future if maturity is to be achieved by the initial operational capability (IOC) of the Tug.

It is axiomatic that the first step of this evolution should be of relatively low cost because the unknowns involved could result in substantial changes as the process continues. For this reason, it was recommended that consideration be given to a joint NASA/USAF effort, mutually beneficial to both parties, with each party assuming a proportionate share of the cost. Current USAF programs offer this advantage. The Space Test Program (STP) is specifically designed to support new space equipment developments, providing a flight test platform for several experiments on a single flight. For these tests, low cost booster vehicles (ATLAS F) are available to support such operations. In addition, it is also possible to deploy a piggyback payload on other USAF launch vehicle operations, e.g., Titan IIIC. Servicing would then be performed on a subsequent launch wherein module replacements would allow extended life for the mission.

These concepts have been considered in light of this immediate application as well as the potential to evolve to a mature operational concept. The objectives of such a pilot program are to demonstrate confidence in the concept, reduce design risks to operational programs, and to identify any operational problems associated with automated space servicing. The major thrust of the effort must be directed at involvement of the payload community to develop confidence in this operational concept.

2. SPACE SERVICING ANALYSIS

The analysis employed in this effort has been directed at assessing the economic benefits of space servicing as applied to a broad spectrum of payloads. Although detail information is not available for future payload designs, it is possible to assess the general character of payload operations as defined by the October 1973 NASA Mission Model, Reference 1. The benefits to be obtained are derived from two sources. Extending the lifetime of a given payload by replacing a module rather than the entire payload allows a reduction in overall payload procurement, assuming the reliability characteristics are essentially equivalent for either design. Also, with modules weighing between 50 and 300 kg (100 and 600 lbs), it is possible to perform multiple-payload servicing on any given upper stage flight. This has the potential to improve overall Shuttle operations, thereby, providing further benefits.

2.1 RECONFIGURATION FOR SPACE SERVICING

2.1.1 Commonality

Achieving these benefits requires a certain commonality of design for the payloads of interest. This is the first step of the assessment process and has been documented in References 2 and 3, Payload Designs for Space Servicing, with Addendum. Forty-two payloads of the reference mission model were reconfigured for space servicing. Representative weight and reliability characteristics were developed for each space replaceable unit (SRU) and non-replaceable unit (NRU). In addition, various levels of redundancy were employed consistent with expendable payload designs employed with the reference mission model. Consequently, the only variance between expendable and space serviceable designs is reflected in heavier weights due to the modularization of the payloads. These data are then employed in a Monte Carlo simulation program to develop random failures of the modules as they could be expected to occur in practice across the mission model. A comparison of expendable versus space serviceable operations can then be made on a common basis to assess the relative merits of each.

A general idea of the reconfiguration process can be obtained from Figure 1. The Earth Observatory Satellite is shown in two concepts. The original concept is space serviceable within the Shuttle bay but the modules are relatively large and adaptability to a wide range of payload operations (e.g., COMSATS), is limited. The modified version employs smaller modules positioned on a ring frame that allows automated module exchange. The same equipment exists in both designs; however, the modules can be standardized for application to other payloads. It is not possible at this time to say what the optimum design is; however, it is felt that the module and structural characteristics are representative of what can be expected no matter what design is accepted. The modules may vary significantly, depending upon the components, but the interface with the basic framework (NRU) is standardized. The number of modules per payload varies between 9 and 27, with an overall average of 13 SRUs per payload. Over 400 modules are required for the 29 unique payload designs developed by this effort. Of these, 104 modules are dedicated to mission equipment and are, therefore, considered unique. The remaining 300 subsystem SRUs are made up of 213 unique designs. This number can be reduced to 34 by standardization while still meeting all performance requirements of the candidate programs.

Principal interest has been placed on geostationary operations with various Shuttle upper stages. There are 16 different geostationary payload programs projected in the reference mission model requiring a total deployment of 114 payloads in the time period of 1980 through 1990. Of these 16 programs, 13 appear to be reasonable candidates for space servicing. The reference mission model was developed in a deterministic manner based upon mean mission duration estimates for expendable payload operations. However, the simulation program employed for this analysis requires a statistical assessment of the logistic traffic based upon the individual reliability characteristics of each element of each payload. Therefore, it is not possible to match exactly the reference

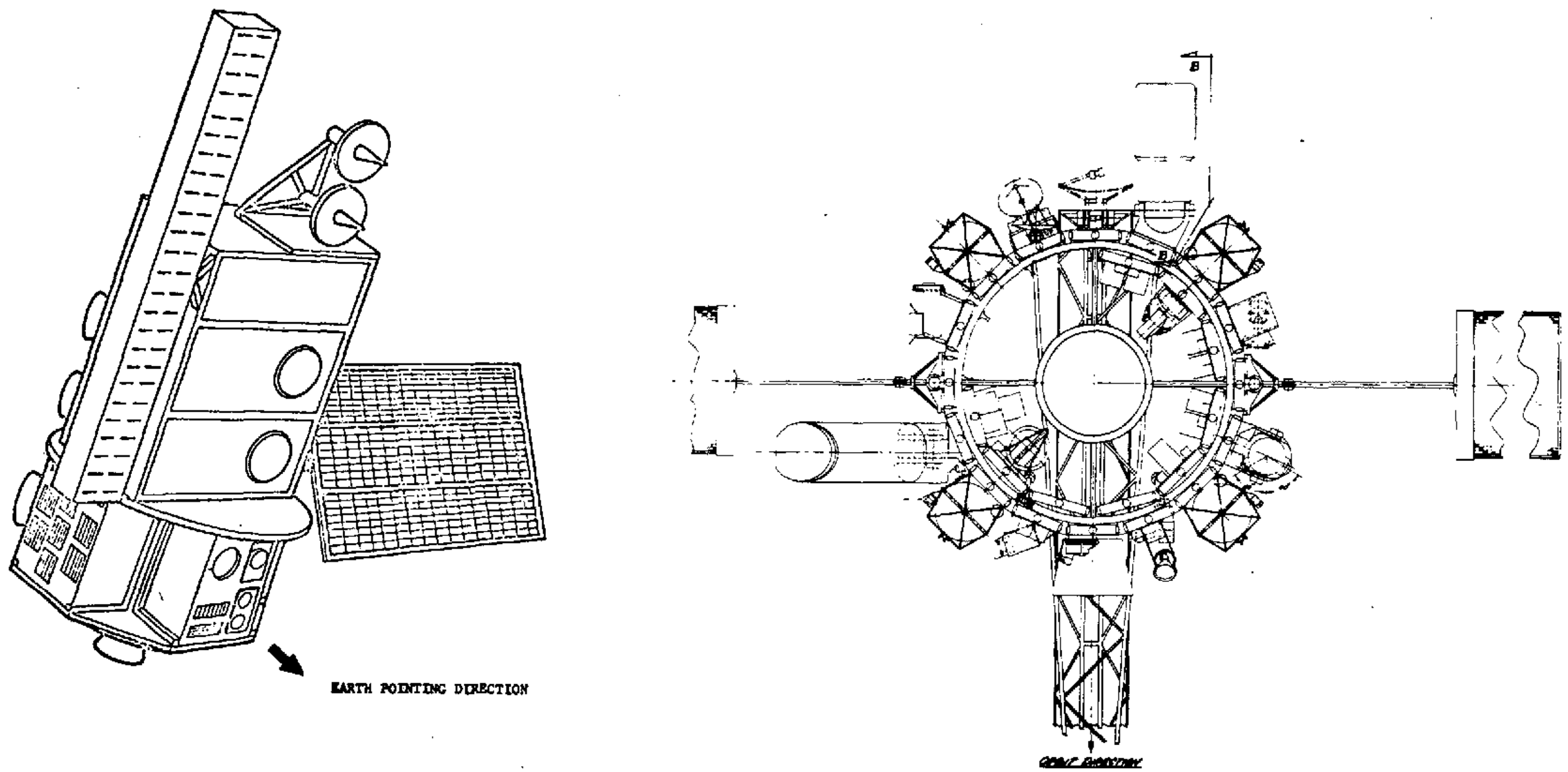

Figure 1. Modified EOS Payload Reconfiguration

mission module but the general character of operations is achieved. On the average, 96 to 98 payloads are deployed over the time period of interest, with the statistical process versus the 114 payloads mentioned above. Hence, the statistical estimates are considered valid for the purposes employed in this effort. These data then form the basis of comparisons with space servicing operations.

2.1.2 Approaches

There are several approaches for space servicing operations that deserve consideration. The important point is to observe the trends of the analysis results relative to overall payload procurement and upper stage/Shuttle flight rates. A third parameter is the number of stages which must be expended due to high weight payloads over the period of interest since this represents an additional procurement cost.

Space servicing may be conducted by deploying modules to a number of payloads, retrieving the depleted or failed modules, and returning the modules to the ground station for refurbishment. To simplify the analysis, the weight of modules retrieved has been assumed to equal that deployed, which is obviously conservative when considering such items as propellant modules.

A second alternative is to not return the failed or expended modules on the belief that standardization of SRUs reduces their cost sufficiently such that the cost of retrieval and refurbishment is not justified. The modules would remain in orbit for disposition at some later date. In actual practice, it probably will be desirable to return mission equipment modules because of their relatively high cost; however, if new low cost developments are being deployed, even this becomes questionable. For ease of analysis, the only item retrieved is the service unit, represented as a 181 kg (400 lb) unit, which remains attached to the upper stage and is repeatedly used.

The third alternative is to leave the service unit in orbit along with the modules which have been replaced. If the service unit is relatively low in cost, this could be desirable because of the performance penality associated with its return. As a rule of thumb, three kilograms of weight can be deployed to geostationary orbit for every kilogram returned. Consequently, this option deserves consideration. It also leads to the possibility of space based servicing operations. At present, the analysis technique requires the upper stage to perform all phasing maneuvers to service payloads at various longitudes. A propulsion module on the service unit could perform this task much more efficiently, thereby enhancing this mode of operation beyond that shown with this analysis. Although the service unit for this analysis is expended after completion of the servicing task, the upper stage is recovered except where heavy payloads preclude this option. In all cases the upper stage performs the required phasing maneuvers for multiple servicing operations.

The actual servicing concept employed when the Shuttle and upper stage become operational will probably be some combination of each of these three modes. Consequently, it is important in any such analysis to examine trends of the operational characteristics. The results can then be compared relative to each option and also to the current mode of expendable operations. In this way, it is not necessary to develop exact cost data, (which at this point in time is not practical for the spectrum of payloads in the NASA mission model) in order to assess the relative merits of each.

2.1.3 Cost Benefits

Table 1 provides the results of this analysis effort in terms of approximate cost benefits based upon the reference cost data given as footnotes. The baseline case is given as using an improved transtage with an apogee kick motor to deploy expendable payloads for the reference mission model, Reference 4. On the average, 96 expendable payloads are deployed to geosynchronous orbit over the time period of interest based upon a series of Monte Carlo simulations. These payloads require, on the average, 83 flights of the transtage. It was necessary to expend 19 transtages because of payload weights which exceeded the round trip performance capability. All flights required expenditure of

Table 1. Cost Benefits of Three Space Servicing Options

GEOSYNCHRONOUS ORBIT (1980 - 1990)

APPROACH	OPTIONS: STAGE	OPTIONS: EXP REC	OPERATIONS: FLTS	OPERATIONS: PL PROC	APPROXIMATE BENEFITS: Δ FLTS	APPROXIMATE BENEFITS: Δ PLS	APPROXIMATE BENEFITS: Δ STGS	APPROXIMATE BENEFITS: Δ COST $M
REF. BASELINE	TRANS / KICK	✓	83	96	-	-	19/83	0
PAYLOADS EXPENDED	CENTAUR	✓	74	96	9	-	-	193
	FULL CAP TUG	✓	48	96	35	-	-	453
SPACE SERVICE RETRIEVE SRUs	CENTAUR	✓	115	64	-32	32	10	23
	FULL CAP TUG	✓	70	64	13	32	2	533
SPACE SERVICE EXPEND SRUs	CENTAUR	✓	90	64	-7	32	10	273
	FULL CAP TUG	✓	59	64	24	32	2	643
SPACE SERVICE EXPEND SU / SRUs	CENTAUR	✓	81	64	2	32	10	363
	FULL CAP TUG	✓	55	64	28	32	2	683

Benefits to be Applied Against
- DDT&E - Payloads and Stages
- Recurring Refurb. Costs
- Additional Mission Ops. Support

Reference Cost Data

Shuttle/Tug Flt	$10M
Transtage	5M
Kick Motor	0.1M
CENTAUR	8M
Full Cap. Tug	10M
Avg. Payload Cost	10M

the kick motor. This then becomes the point of reference for comparison relative to overall operational benefits.

A substantial improvement is derived from use of the full capability Tug (Reference 5) to deploy the same payloads over the same period. The number of upper stage flights, and hence Shuttle flights, can be reduced by over 40%. This creates a cost delta or benefit of approximately $450 million as an average value, which can be applied against the DDT&E and refurbishment costs of the upper stage. A substantial improvement is also achieved with the large tank Centaur (28 ft or 8.5m in length). Because of its improved performance, it was not necessary to expend any upper stages; i.e., all payloads could be deployed and the stage recovered.

When space servicing is employed, the equivalent payload procurement is, on the average, reduced by over 30% while still meeting all mission requirements. Some of this advantage is discounted though by the increased number of flights required due to the heavier payload weights associated with space serviceable designs. If all modules are returned, the incremental savings over expendable operations with the full capability Tug is an additional $80 million. This does not include the effect of refurbishing the modules for subsequent reuse, which could provide further savings. Equivalent payload procurement is based up both the number of payloads deployed and a ratio of the SRUs required to maintain operations. If a non-replaceable unit fails, it is necessary to replace the entire payload. If one-third of the SRUs are replaced over the period of interest, it is assumed that one-third of the average payload cost is incurred. This ratio, along with a low average payload cost of $10 million, reflects very conservative cost benefits. The benefits of module refurbishment could provide a further increase in benefits. Since refurbishment costs are very speculative, they have not been incorporated in this analysis. An estimate of what might be expected is addressed later in this report.

Expending the modules, but returning the service unit accumulates an additional increment of $110 million. The same number of modules are required in either case. Leaving the SRUs and SUs in orbit after completing servicing increases the total potential benefits from space servicing to $230 million. This should be more than adequate to compensate for DDT&E costs to develop space serviceable designs and servicing equipment. In addition, these results should be conservative from the standpoint that payload weights have a substantial margin and the cost employed for Shuttle operations is relatively low. If the average payload costs and the cost of a Shuttle/Upper Stage flight are increased above $10 million, the benefits from servicing will increase proportionately.

For purposes of comparison, results are also shown for the large tank Centaur. The excessive boiloff rates preclude its use for any missions requiring extended periods on orbit. However, as the return weights are decreased, it becomes easier to absorb the propellant boiloff and still accomplish the mission. Extending this point further implies that the large tank Centaur may be a candidate upper stage if a space based service unit is employed wherein the Centaur mission duration is minimized.

The conclusions which may be drawn at this time are that space servicing, over the broad spectrum of applications, will provide sufficient cost savings to more than compensate for the DDT&E required to achieve this concept. Recalling that not all payloads were reconfigured for space servicing, the indication is that a rational mix of expendable and serviceable operations can be achieved. The total time period involved is eleven years. If the associated DDT&E to achieve space servicing can be maintained at $100 million, the concept pays for itself in less than five years. Or, if only one-half of the payloads employed in this analysis accept space servicing, the concept is still favored over purely expendable operations. Further, the analysis results indicate that implementation of any initial concept should not preclude growth to space based operations which hold the promise of further cost improvements.

2.2 IMPLEMENTATION

Consideration should be given to implementation of space servicing relative to the payload program opportunities of the referenced NASA mission model. Figure 2 shows the 16 programs scheduled for geostationary operations. If space servicing is to be introduced, it can be expected that a payload program would alter its current design approach only when a new start or major modification was scheduled. In this way, the impact on each payload design to incorporate servicing should be minimized. Since payload programs will accept space servicing only as it serves their individual needs, it may be several years after the first serviceable design becomes operational before a large family of payload programs is accommodated.

The new starts shown in Figure 2 reflect those occurring after the Shuttle IOC. The first candidate is an explorer payload in 1980, followed by the Synchronous Earth Observatory Satellite in 1981. It may be possible to also influence one or two of the domestic programs having new starts in 1981, but the majority of these types of programs will probably wait until the servicing concept has been demonstrated on NASA operational programs. The important point, however, is to examine the general character of new or major program investments as a function of when space servicing would be introduced as an operational reality.

This may be more easily recognized by integrating the new starts as a function of time as shown in Figure 3. Thirty-four new starts or major revisions have been scheduled over the time period of interest. Most of these programs involve two or more payloads resulting in a total deployment of 96 payloads. The general character of new starts and payload procurement is reasonably linear. There are no large peaks or valleys, indicating a relatively stable level of funding to

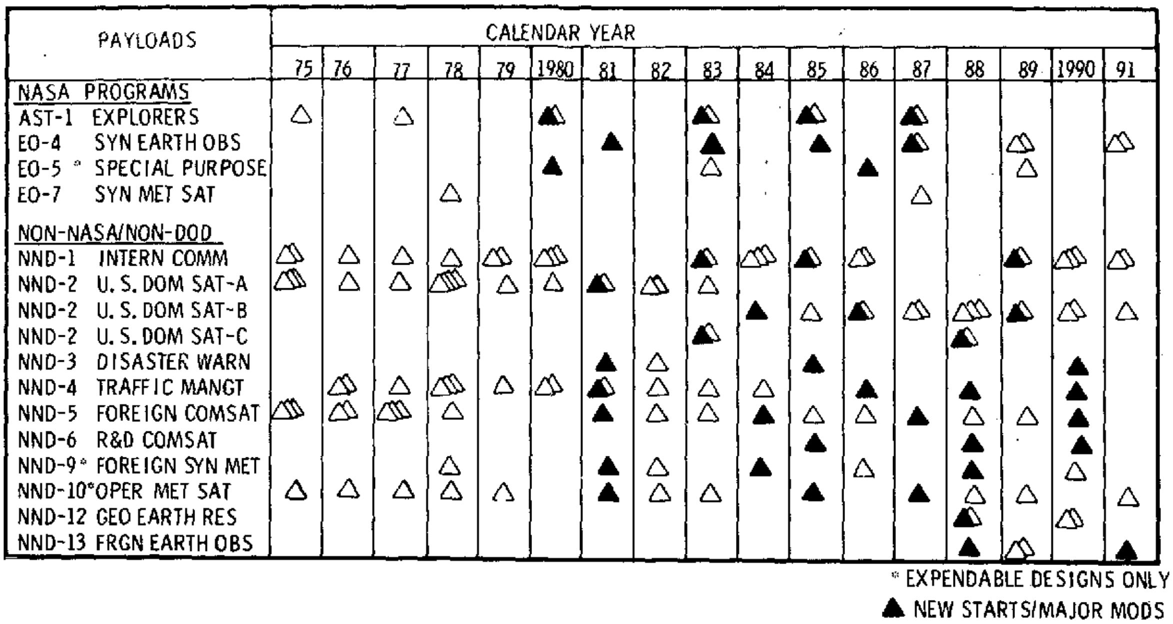

Figure 2. NASA and Domestic Geostationary Programs

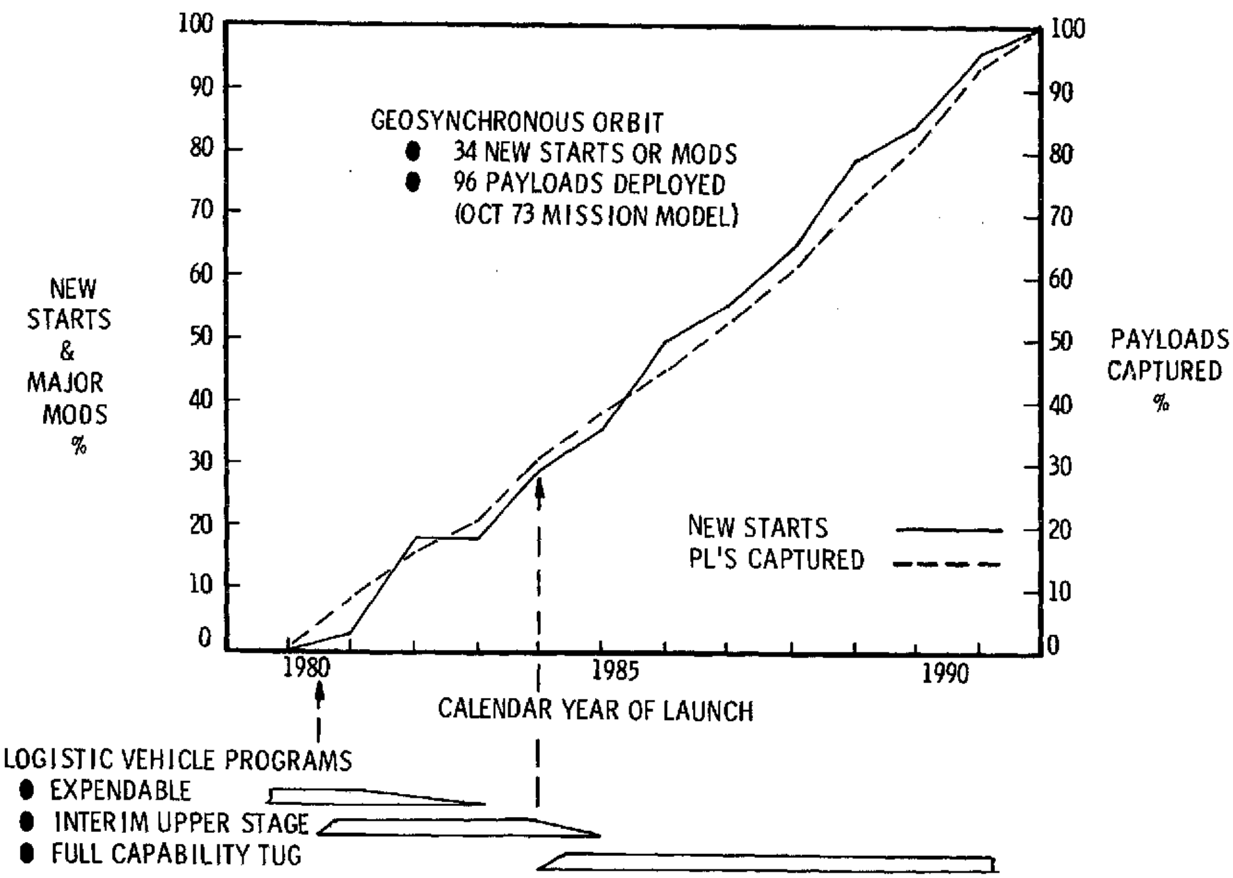

Figure 3. Major Payload Program Events

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support a steady growth of activity. This figure also shows that if space servicing becomes operational with the full capability Tug in 1984, over 70% of the programs could be captured. In addition, if an interim servicing capability existed prior to this time, other programs could be captured, providing the foundation to build to the operational concept in 1984. The economics of interim servicing are probably not favorable because of performance limitations, but the experience gained would be very influential on subsequent programs. This point is very apparent when considering the loss of benefits due to the delay of introducing space servicing as shown in Figure 4.

The loss in benefits can be substantial if servicing is delayed until the Tug becomes operational. Nearly 50% of the cost benefits shown in Table 1 are influenced by the first few years of activity. This reflects the fact that if a new start is not captured in the first few years, the opportunity does not present itself again for another four to six years later. Therefore, those benefits which would occur during this period, would be lost. This characteristic holds independent of the servicing concept of interest. Emphasis should obviously be placed on capturing as much of the early traffic as possible, again supporting the argument for an interim servicing capability.

2.3 REFURBISHMENT BENEFITS

It is also important to note that these results should be considered conservative. Further optimization could be achieved by improving module weights, the sequence of selecting payloads to be serviced, and the manner of responding to warning incidents rather than failure occurrences. The results obtained were sufficiently clear that further optimization was felt unnecessary at this point in time. As an example, the results shown have not taken advantage of refurbishment and reuse of space replaceable modules. For the purposes here, if a payload required five of its 15 SRUs to be replaced over its opera-

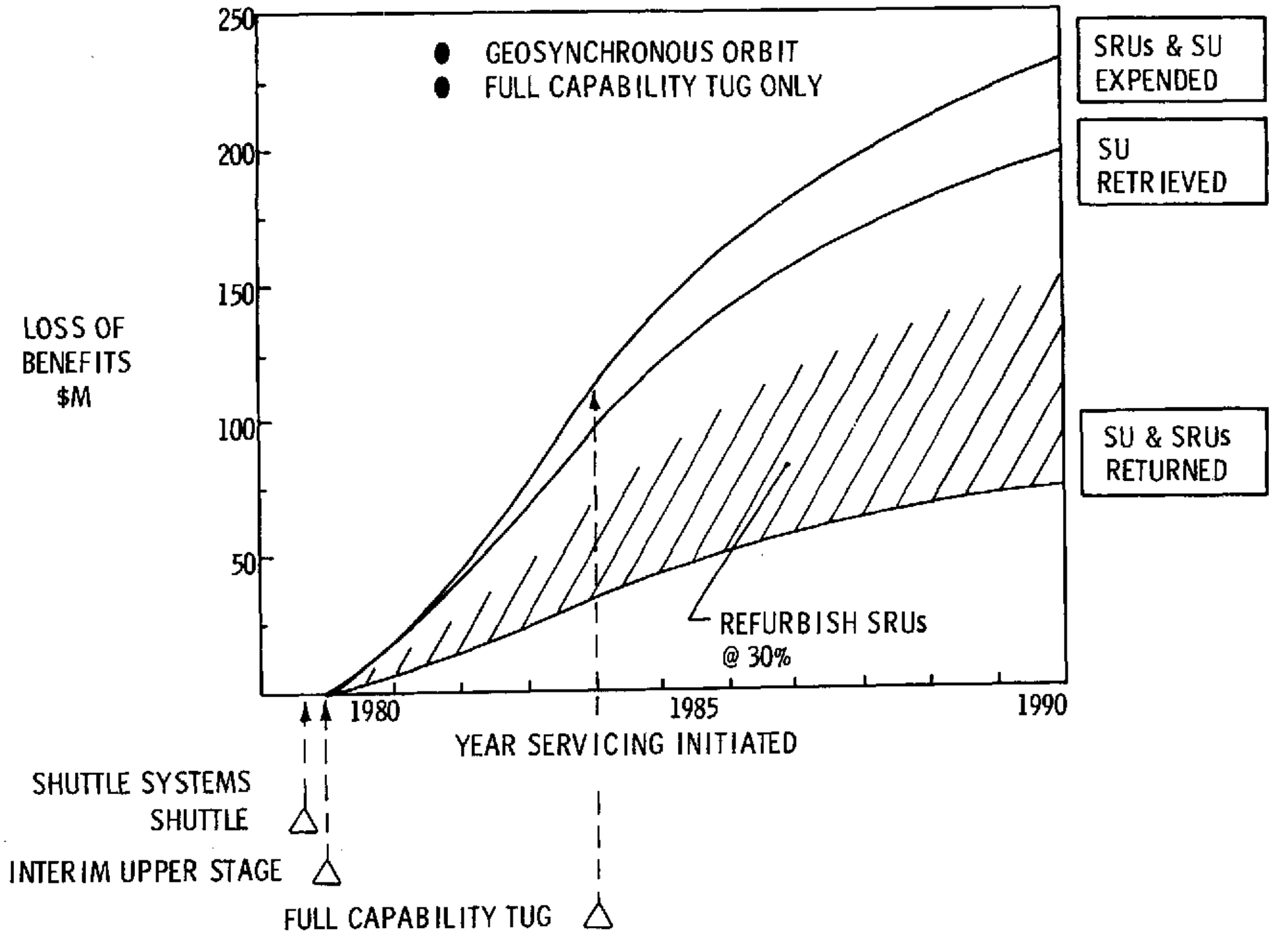


Figure 4. Cost Impact of Delaying Space Servicing

tional lifetime, it was assumed that one-third of the cost of a new payload was incurred. This conservatism was selected because future payload programs are only speculative at this time, with very little hard design information available. However, it is well known that subsystem modules should be less expensive than mission equipment modules, and also that the non-replaceable unit (structure, solar panels, highly reliable components) will be a substantial part of the payload cost. Consequently, replacing five modules, of a 15-module payload, may only represent 20% or less of a total payload buy, thereby inherently providing further benefits beyond those derived in this analysis.

Although the cost benefits of refurbishing and reusing space replaceable modules are vague because of numerous uncertainties, it is possible to gain some insight on this subject in the following manner. If the total number of SRUs required over the time period of interest could be refurbished for 30% of their original costs on the average, the improved benefits would be as indicated in Figure 4. The savings of $83 million would be increased to approximately $150 million: an improvement of nearly 100%. However, for the conditions employed here, these savings still do not match the benefits associated with no retrieval of the SRUs, also shown in Figure 4. This is brought about by the impact on the Tug performance associated with geostationary retrieval operations, forcing an increase in the number of flights to satisfy the same servicing requirements. It is further noted that even if refurbishment costs were zero, it would still be more advantageous to expend the modules on the average. Of course, this is based upon an average payload cost of $10 million. If the cost is substantially higher than this, the pattern could reverse. This is only an average though, and in specific cases retrieval and refurbishment should be considered, especially if excess Tug performance exists at the time of interest.

In summary, the results of this analysis indicate that preparations for space servicing should be initiated immediately in order to capture a majority of new program starts in the 1980 time period. It requires three to five years to develop a new payload. Before a given payload program will accept space servicing, it will be necessary to provide convincing evidence that benefits are real and the associated risk is low. This will require an additional two to three years, resulting in an overall period of time of five to eight years before substantial progress can be seen. Consequently, the only rational approach is felt to be one of timely evolution from an initial proof test to a mature operational concept coincident with payload program acceptance. If this process is not initiated in the immediate future, numerous payload programs will be lost to space servicing if not totally, at least until a subsequent generation arrives.

The major obstacle that must be overcome is the inertia inherent within the payload community to alter their current course of operations. Their involvement at the beginning of this evolutionary process is essential to assure acceptance. The initial test case may be unsophisticated, with its objective to develop confidence in the concept. However, the selected concept should also meet at least the following criteria:

a. Constraints to be imposed upon payload design and operations must be minimized, recognizing that both standard and non-standard interfaces may exist.

b. The selected servicing concept should not preclude growth to space based operations since the economics favor this direction.

If these objectives can be achieved, there should be a great deal of activity for space servicing and maintenance of future space programs at all orbital altitudes including manned and automated operations.

Future applications are discussed briefly in the next section of this report followed by pilot program options.

3. PROGRAMMATIC ASPECTS

Any new concept under consideration should be viewed in light of its contribution to the total space effort. Therefore, it is felt desirable to consider the place of space servicing in the overall scheme of future space operations, what growth capability should exist, and what development schedule is necessary to achieve a mature operational status.

3.1 OVERALL SPACE EFFORT

The overall technology involved in developing a space servicing and maintenance capability must embrace a wide variety of new program options. Manned maintenance activities in low altitude orbits have been a serious consideration for some time and have been reinforced by the recent success of the Skylab operations. Continued development of this capability can be expected to follow the path shown in Figure 5. Current studies and development efforts will inherently lead to large free-flying spacecraft such as the Large Space Telescope which require periodic and possibly unscheduled maintenance operations. Retrieval of hard copy data, replenishment of consumables, and adjustment or realignment of instruments are typical manned operations.

This should eventually lead to assembly of large structures in space, either as manned or unmanned spacecraft but certainly involving manned support for the assembly process. This development process seems inevitable to achieve more efficient space operations. Spacecraft will inherently become larger and more complex and incorporate a wide spectrum of mission equipment. In this way, multi-mode operations can be performed with a single platform rather than creating new spacecraft each time a state-of-the-art improvement is achieved in sensor developments. The benefits of manned servicing can be both in maintenance and management of the platform operations.

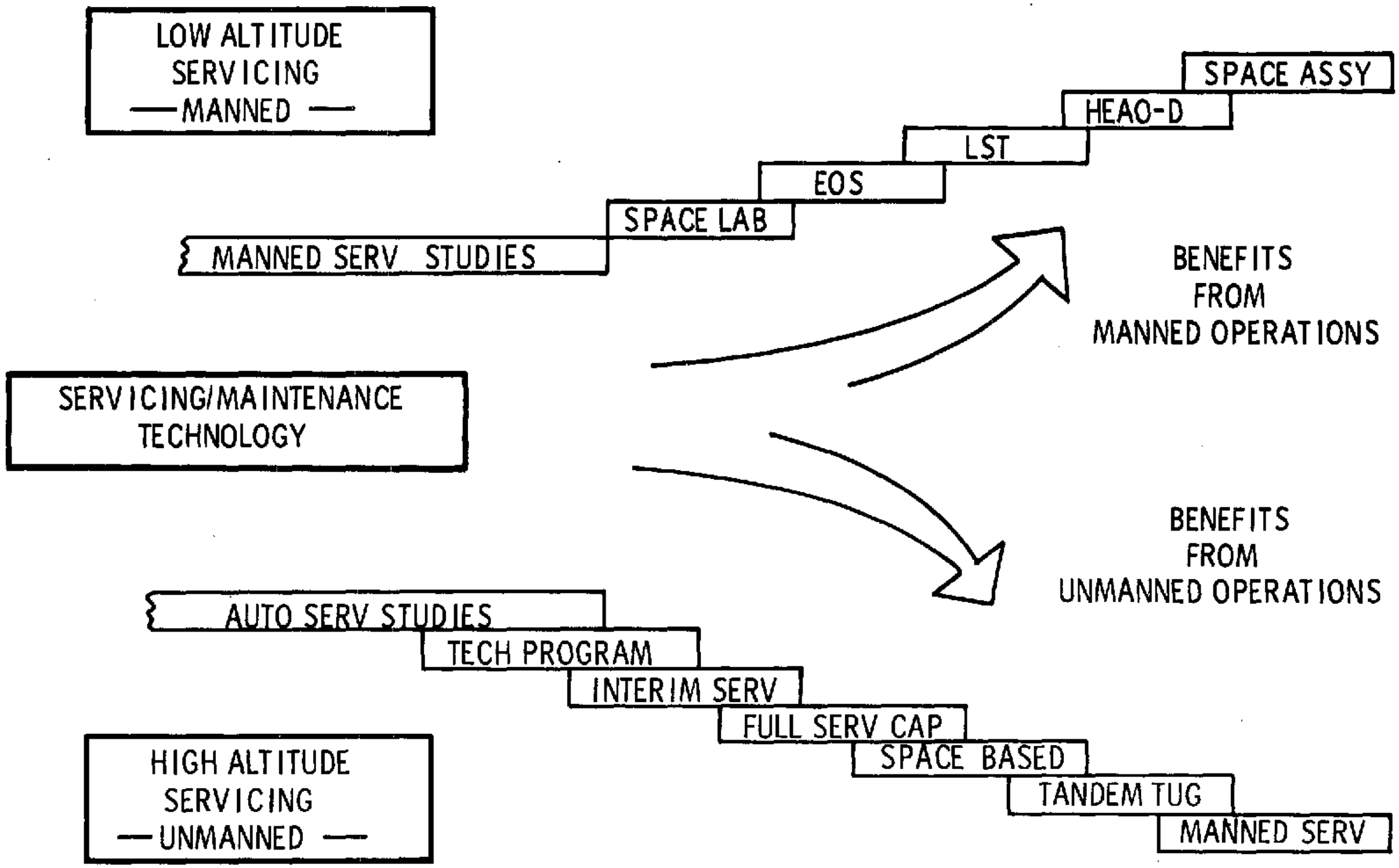


Figure 5. Programmatic Aspects of Space Servicing

A similar scenario exists for geostationary operations; however, upper stage performance capabilities will force servicing operations to be primarily automated for a period of time until the need for manned maintenance is justified. The overall technology evolves from current study efforts of various servicing concepts and the impact on payload design efforts. This evolves, among other things, into a pilot program as possibly the first step of this evolutionary process.

3.2 GROWTH CAPABILITY

Following a Pilot Program, the next step is to provide an interim servicing capability to support those initial space serviceable payloads introduced in the early 1980 time period. A full servicing capability then evolves when the full capability Tug becomes operational.

This growth should continue as more and more payload programs take advantage of space servicing economic benefits. As the payload community expands, the need for space based operations to satisfy these servicing requirements may possibly lead to warehousing of modules on orbit. A possible space based servicing unit (SSU) is shown in Figure 6. This unit could be a direct copy of the equipment employed in the initial pilot and interim servicing programs.

The propulsion unit, with an avionics package, would be supplied with a service unit and replacement modules by a Tug flight to geostationary orbit. The space based unit performs all rendezvous and docking functions with the Tug, acquiring the service unit and modules. The SSU then transfers from one payload to another, performing servicing as needed. The performance of this unit is such that several payloads could be serviced over a period of 10 to 20 days. When servicing is completed, the SSU loiters, waiting for another Tug flight.

One other point is indicated with this schematic. The payloads being serviced will probably consist of both standard and non-standard modules. This appears unavoidable because of the wide variance in mission equipment which may be employed. Consequently, the service

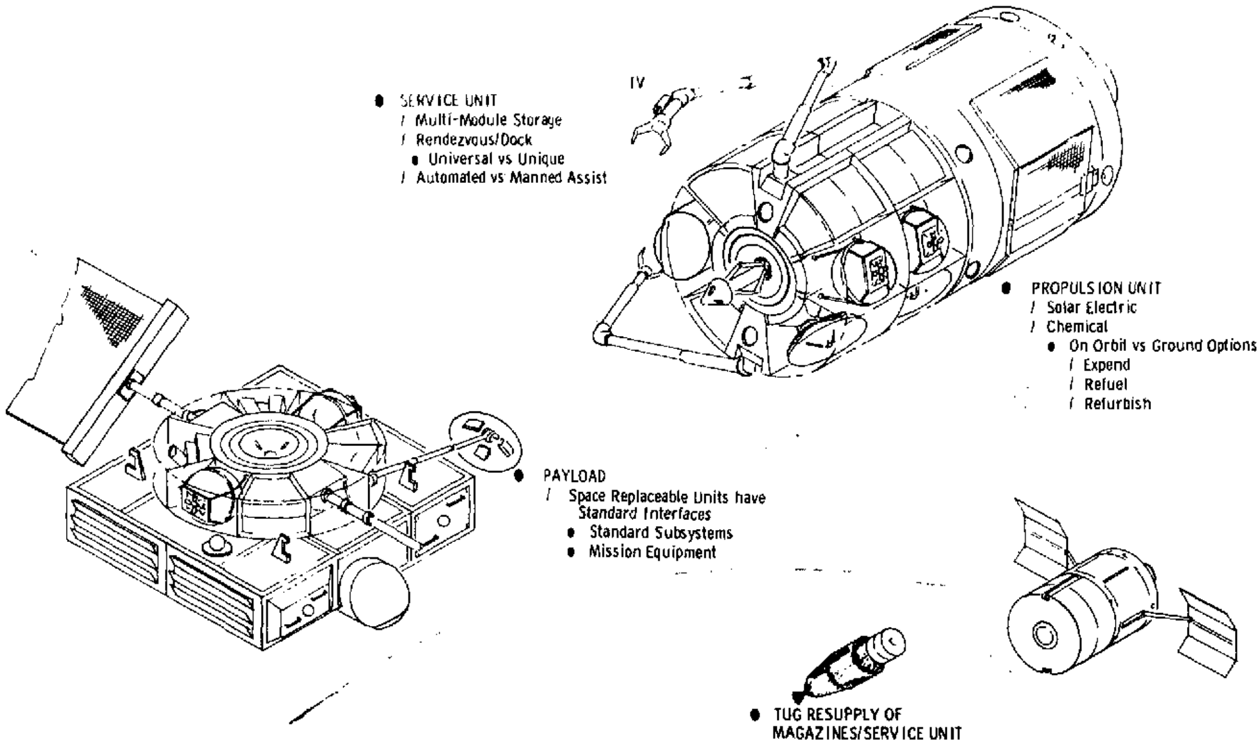


Figure 6. Automated Servicing Concept for Space-Based Unit

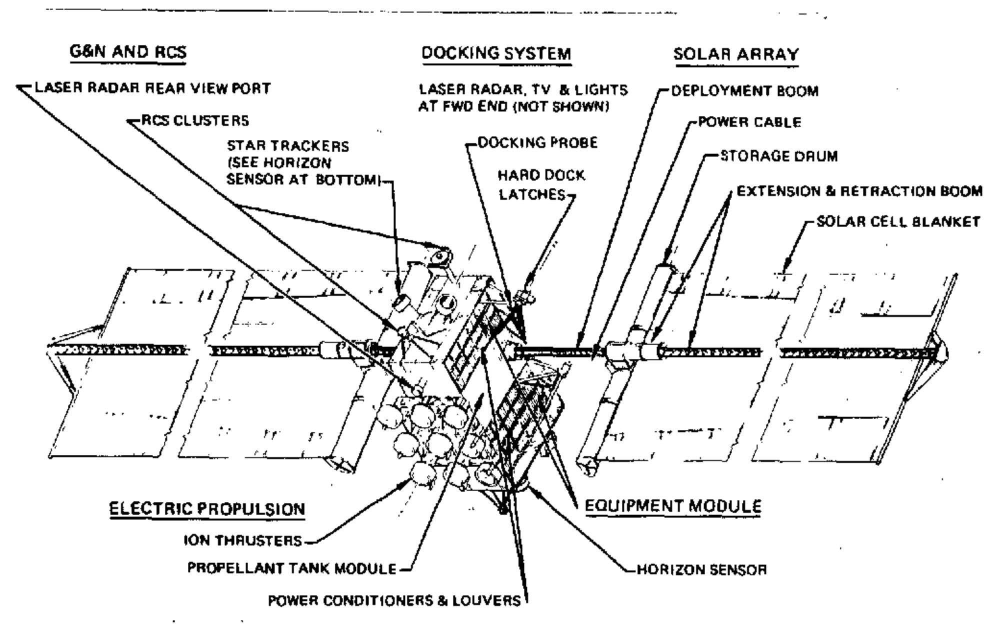


Figure 7. Space-Based SEPS Servicing Concept

unit may require both a hard dock as well as a stand-off capability for exchanging modules. The hard dock approach is desired to minimize the uncertainties in locating and replacing modules; however, oversized modules may require manipulators for removal and installation. The modules and SSU may be returned for refurbishment or discarded in space depending upon overall economic considerations.

Further growth is available by extending this concept to a solar electric propulsion stage, SEPS, as shown in Figure 7. The performance efficiency in a space based mode is unparalleled. The time to phase from one longitude to another is very competitive with a chemical propulsion stage and its inherently long life and high specific impulse make an excellent combination for this task. In addition, if large payload weights exceed the Tug capability, the SEPS can transfer to a lower altitude, retrieve the payload, and place it in geostationary orbit. The same service module could be employed as previously shown, adding extra wafers of magazines as needed. The capability offered by this vehicle cannot be denied. It is necessary, however, to develop the servicing system to go with it, hence the earlier statement that any such development should not preclude growth to space based operation.

Finally, as payloads become more complex and highly sophisticated, it is inevitable that direct manned maintenance operations will be required. If prior operations evolve properly, extending man's region of influence to geostationary orbit should represent a natural occurrence. In this event, a tandem tug operation will be required taking advantage of the space assembly techniques previously developed in low earth orbit. Tandem tug operations can provide a round trip capability of approximately 5, 000 kg (11, 000 lb). A two-man service capsule as shown in Figure 8 is estimated conservatively to weigh 3, 200 kg (7, 000 lb), leaving approximately 1, 800 kg (4, 000 lb) of payload for servicing operations. Duration of the operation as envisioned here would be seven days to remain compatible with the Shuttle/ Tug design constraint. Sufficient reserves exist for an additional 10 to 14 days in the event of a tug failure on orbit. Both stages of the tandem

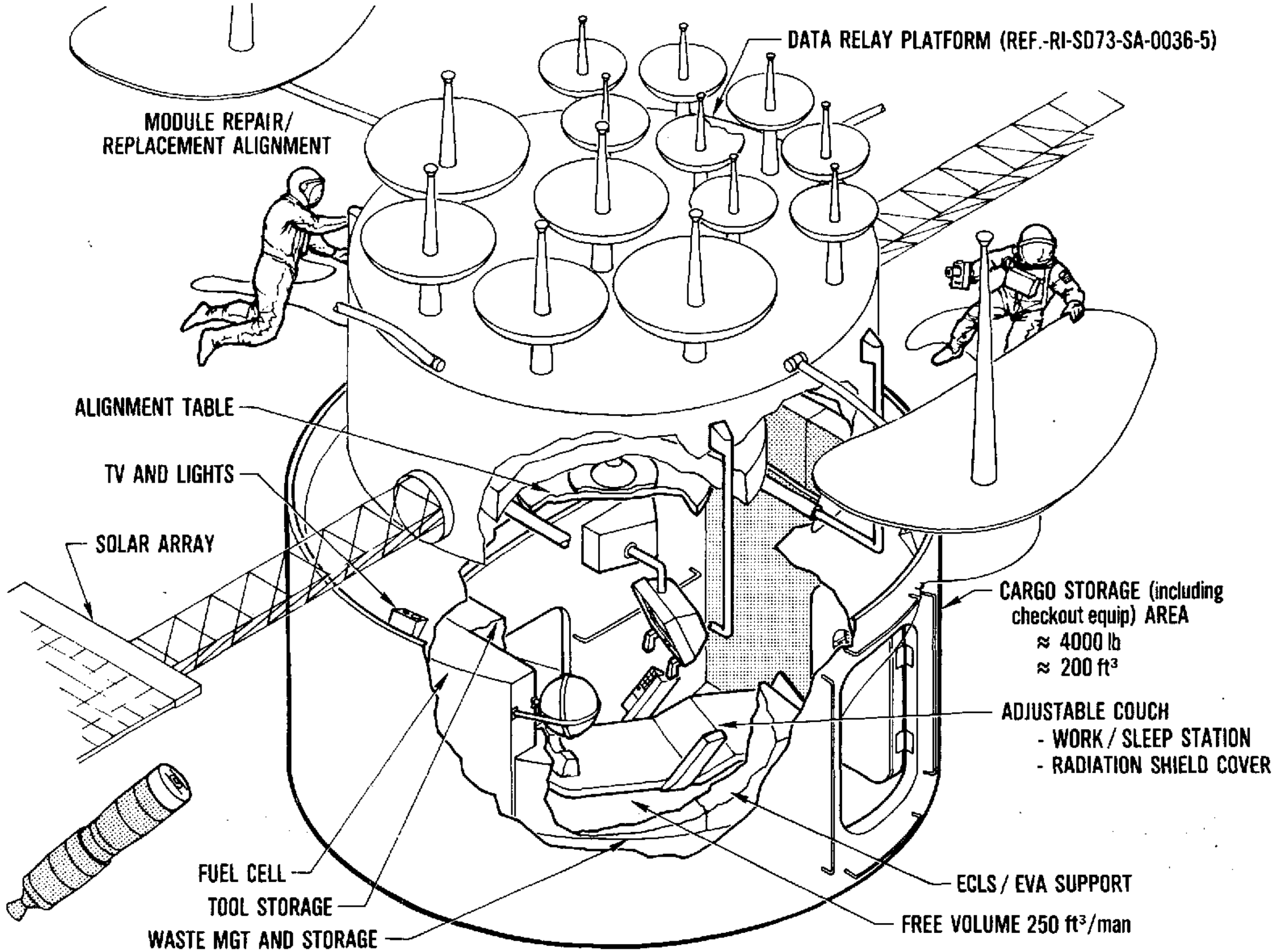


Figure 8. Manned Maintenance Concept in Geostationary Orbit

tug would be recovered.

In summary, there is a direct link between low earth orbit manned operations which extends eventually to manned geostationary missions. Until such time that the demand will justify it, however, high altitude servicing missions will have to be performed with automated or semi-automated vehicles that can remove and replace specific modules. The process of arriving at this capability is discussed next.

3.3 DEVELOPMENT SCHEDULE

Space servicing developments should precede by a very short period of time the payload development efforts, as indicated in Figure 9. The rationale for this lies in the belief that payload developers will be hesitant to alter their design approach unless a service concept has been demonstrated. However, if the service system matures too rapidly, it is inevitable that the service mechanism will impose constraints upon the payload design, thereby inhibiting the acceptance of the concept within the payload user community. For these reasons, a three-phase development is postulated.

The first phase is a low cost pilot program with a simplified service unit concept and operating on low cost experimental payloads. The results of this test case feed directly into the first generation service unit design effort, and also into a limited number of new payload program starts. These are operational programs which can be serviced on an interim basis pending development of a full capability Tug. After a year or two of operational experience, it should be possible to convince domestic programs to accept space servicing. However, at this point they may want to impose new requirements for servicing thereby leading to a second generation, or mature servicing concept. Extrapolating beyond this time to space based operations is only dependent upon the size of the community to be serviced as opposed to any substantial new developments.

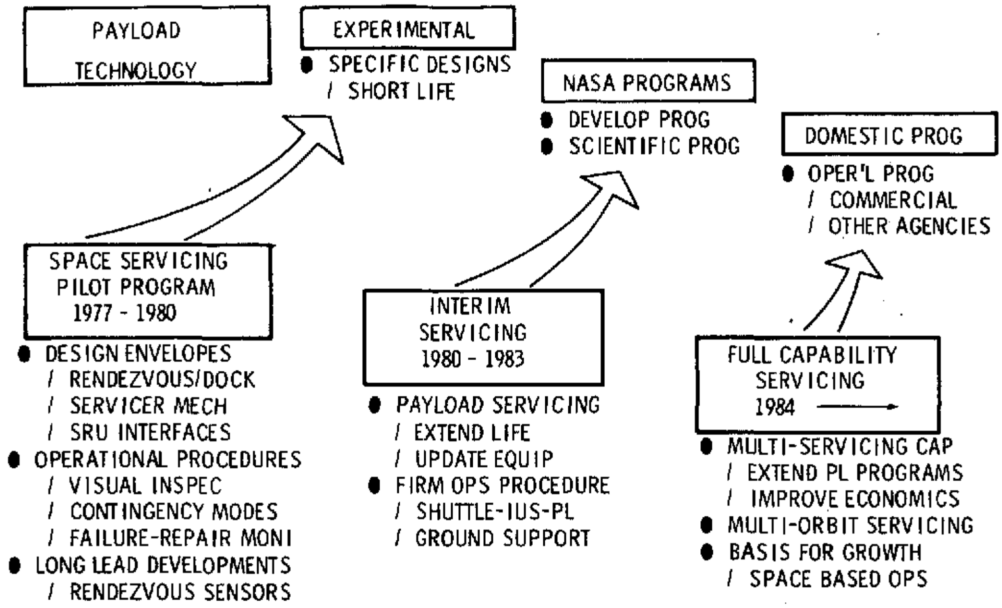


Figure 9. Space Servicing and Payload Development Phases

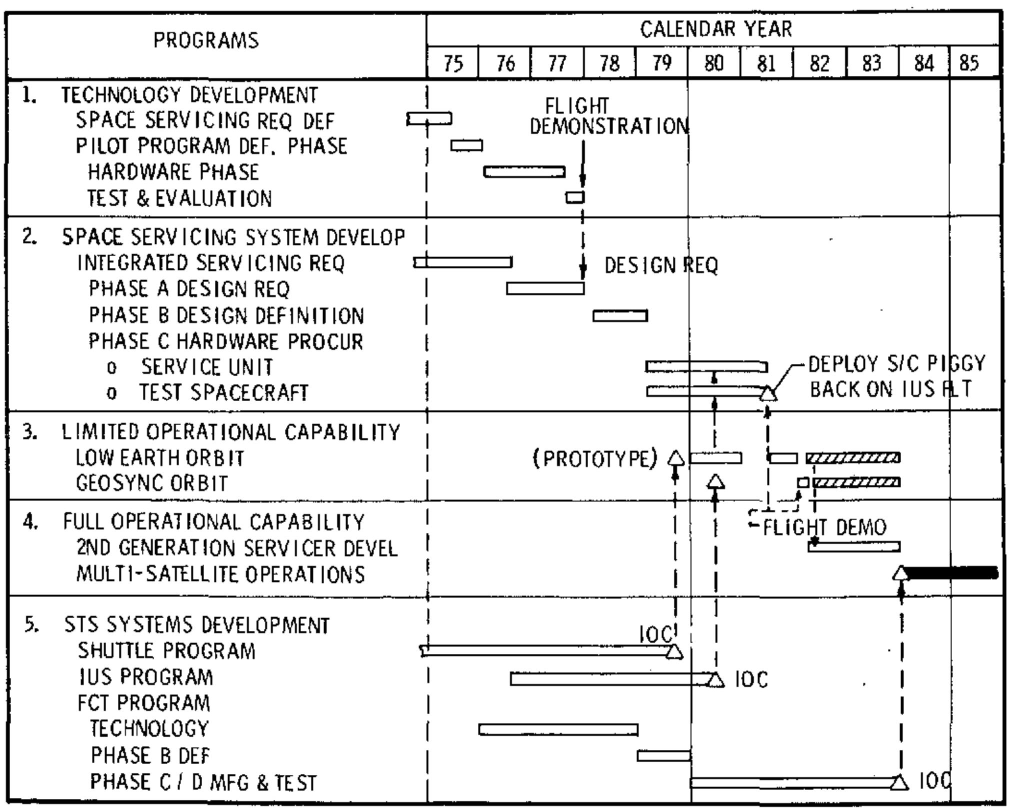


Figure 10. Overall Space Servicing Development Schedule

The three phases dovetail very well into a total program plan development schedule as shown in Figure 10. The pilot program needs to be accomplished by early 1978 to input test results into the first generation service unit development. In fact, it is very problematical that the Phase C hardware procurement can be initiated without the pilot program inputs because of the lack of support from the payload community. The pilot program has to stimulate payload development efforts, otherwise, there will be no payloads to service when interim servicing becomes operational because of associated lead time requirements.

Low earth orbit servicing could be demonstrated late in 1980 with a geostationary operation in 1981. An experimental payload (explorer class) could be deployed piggyback on a normal upper stage flight. Subsequently, servicing could be performed by the interim upper stage with a piggyback service unit and modules. This would be the first demonstration of the full operational sequence, including longitudinal phasing maneuvers. By this time, the foundation should exist for a second generation development effort to arrive at a mature servicing concept, to be developed in conjunction with the full capability Tug. During this development effort, servicing could be performed by the interim upper stage as required. Although it may not be economical, due to performance limitations, it would provide support for those payload programs that are willing to accept the risk prior to the IOC of the full capability Tug.

This schedule does not allow any substantial margin for delay. If a full servicing capability is not instituted early in the Shuttle era, the cost benefits previously identified will be lost. A delay in initiating positive action will result in greater inertia within the payload community and, as previously pointed out, payload technology must parallel servicing system developments. It is not rational to expect at the initiation of the first servicing system development that a broad spectrum of payloads will have accepted space servicing. Design requirements will invariably evolve at a later date which cannot be ignored and which must be accommodated by the next generation. The overall effort needs to be initiated immediately to have any hope of an orderly progression that can build from one plateau to another. Options which can support this process are discussed in the following sections.

4. PILOT PROGRAM OPTIONS

4.1 OBJECTIVES

The objectives of a pilot program are often arbitrary and must eventually evolve to a management level because the decision to initiate the stepwise process to develop a new operational concept is, on the whole, a management level decision. There are no insurmountable technical problems and arguments based solely on the technical aspects of this decision process will miss the true benefits that can accrue from the proposed pilot program. There are several approaches which may be employed to investigate specific technical details, but the major objective is to achieve a cooperative effort which involves both the Shuttle/upper stage developing agency and the payload development agencies. In this way, servicing can progress as a unified effort. One method is through a cooperative flight test pilot program as presented in this report. The urgency for initiating such action has already been discussed in preceeding sections. However, the question invariably arises as to why an investment is required in a pilot program as opposed to other alternatives.

In response to this question, the following arguments for a pilot program are offered for management's consideration.

a. A pilot program is required to develop confidence in the concept of space servicing before the payload community will alter their course of activities.

b. A pilot program is required to demonstrate that the design risks, which must be accepted by the payload community, are not substantial and that through this effort those "risks" can be reduced.

c. A pilot program is required to identify fundamental operational problems associated with automated space servicing which can never be adequately demonstrated by ground simulation efforts.

d. A pilot program is required because a properly managed low cost effort early in the development process can substantially reduce subsequent development costs by early involvement of the payload community to focus on their individual and collective needs when operating with the Shuttle system.

Placing these arguments in context with the development schedule shown previously emphasizes the importance of timing to arrive at a mature space servicing concept when the full capability Tug becomes operational. Although the design process in any one phase can be shortened, this is not likely to increase acceptance by the payload community. On the contrary, an early design freeze may minimize acceptance and utilization if it convinces payload users the space servicing concept cannot meet their needs effectively. A pilot program has the potential to overcome this reluctance with a relatively low investment in keeping with a stepwise "crawl before you walk" development plan. Therefore, the next subject is what options are available for management consideration as an initial step and what investment is required.

The first consideration of a low cost program is to utilize existing equipment wherever possible to reduce development costs. A second factor is to share overall program costs by accomplishing other objectives in addition to space servicing with a single operation. With this in mind, it was possible to develop a matrix of test objectives versus hardware concepts. Two approaches were selected for consideration. Each meets a number of test objectives but to varying degrees. One option employs a primary satellite and a maneuvering unit on a single flight, demonstrating terminal rendezvous and docking, modular exchange, and interface verification. This option has been identified as the WTR option and will be covered below. The second option employs two flights: an initial payload deployment followed after a time interval by a second flight to replace modules and extend the payload operation. This is identified as the ETR option described in section 4.3.

4.2 WTR OPTION

The first option, operating from the Western Test Range (WTR) at Vandenburg Air Force Base, is shown schematically in Figure 11. This operation would be performed in conjunction with the USAF

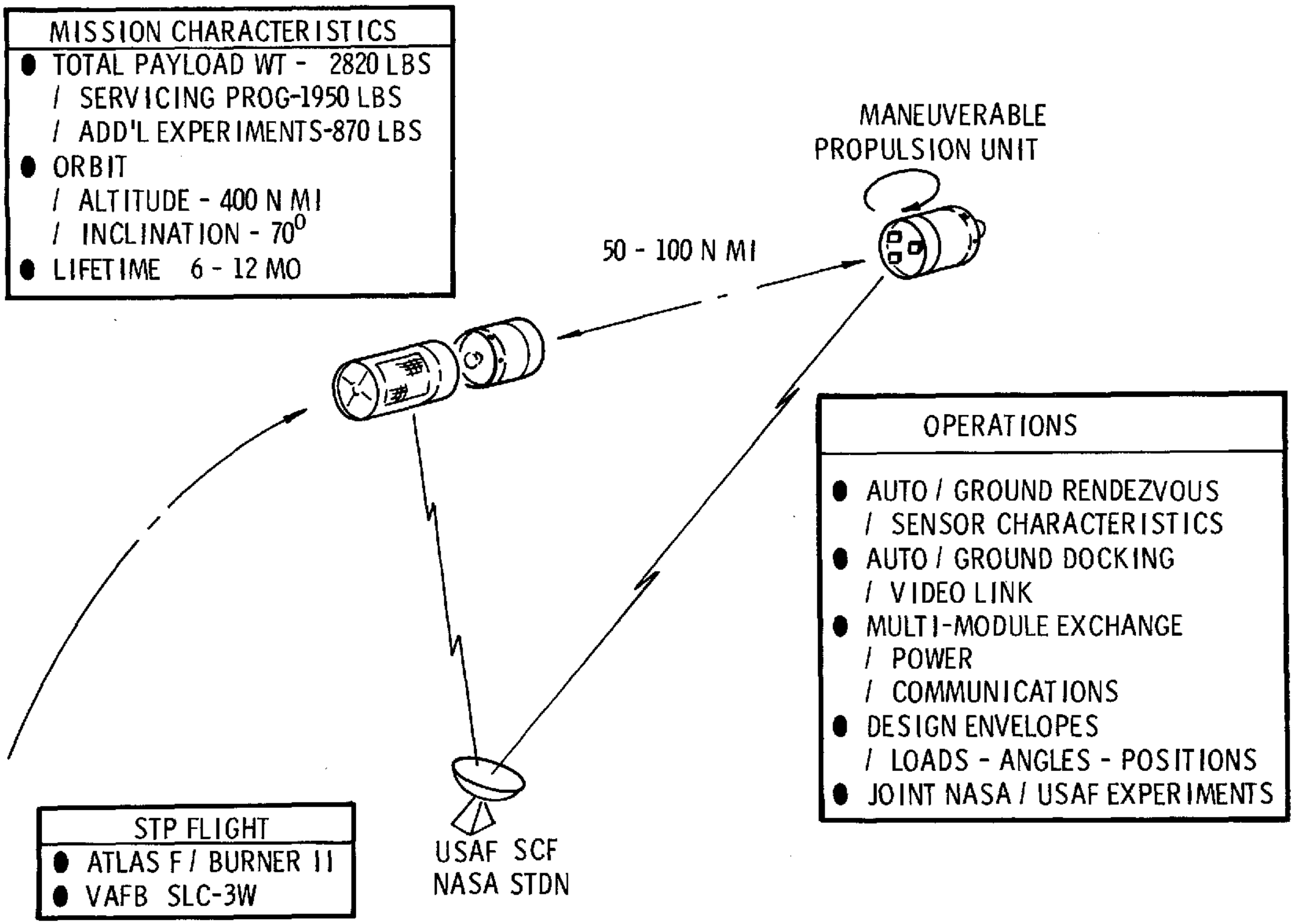


Figure 11. WTR Pilot Program Option

Space Test Program (STP) with responsibility for all USAF activities to be managed by that office. The launch vehicle would be an Atlas F/Burner II combination. Atlas F vehicles are currently in storage and available to support STP operations at low cost. A total of 1280 kg (2820 lb) can be placed into a 740 km (400 nmi) orbit with an inclination of 70 degrees. Of this, approximately 400 kg (870 lb) is available for STP or NASA experiments over and above the space demonstration requirements.

After insertion into orbit, the propulsion unit would be maneuvered to a position approximately 185 km (100 nmi) away from the primary payload. Rendezvous systems would be employed to perform the closure and docking maneuver. The operation can be performed repeatedly to develop operational envelopes, impact loads, sensor characteristics, etc. Ground support would be available through the USAF Satellite Control Facility (SCF) with the capability to support a video link and uplink command to interact with onboard systems.

Candidate hardware is shown in the next few figures. The primary satellite could be the basic satellite body of the USAF STP P72-2 program (Figure 12) currently scheduled for launch in mid-January 1975. With the STP experiments removed, this vehicle has a diameter of approximately 1.5 m (5 ft) and a length of approximately 1.5 m (5 ft). Three axis stabilization and a wide band communication system are provided along with power and thermal conditioning. This vehicle is manufactured by Rockwell International. Selection of this vehicle, among others, would rest with the USAF STP office and depend upon the overall mission objectives.

The propulsion unit could be a Minuteman fourth stage, as shown in Figure 13. This unit is currently in production at Bell Aerospace Company and is capable of transferring 454 kg (1000 lb) of payload through a velocity increment of 305 m/sec (1000 fps). Vehicle weight, including an avionics package, is estimated to weigh 317 kg

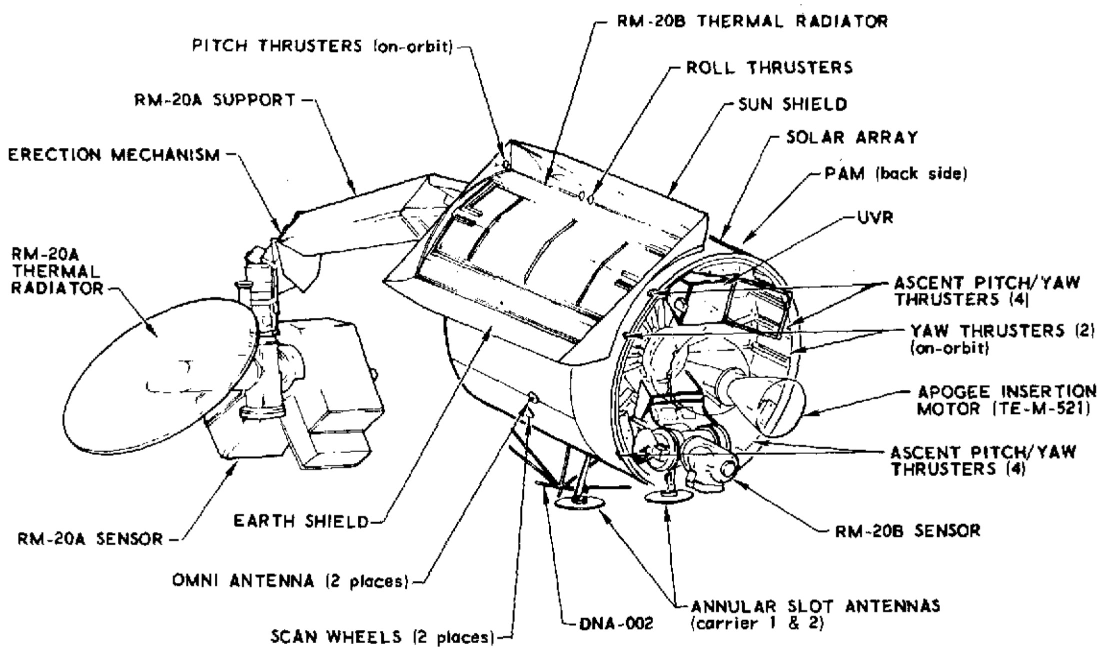


Figure 12. Candidate STP Spacecraft

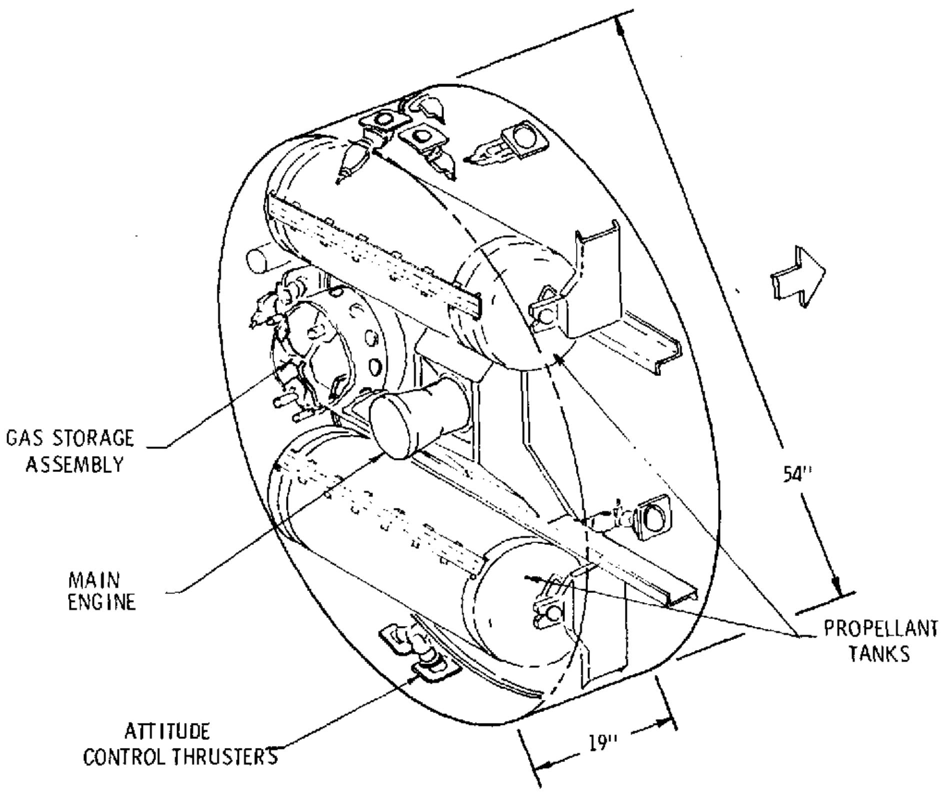


Figure 13. Bell Aerospace PSRE Module

(700 lb). Both vehicles can be packaged within the existing fairing of the P72-2 program.

Further consideration was given to a useful experiment that could be conducted in conjunction with the space servicing operations. One such test could be laser communications. A test flight has already been requested by the cognizant USAF office for the 1978 time period. The test, as currently envisioned, would be limited to a space to ground link. A candidate hardware concept is shown in Figure 14. If this effort were combined with the servicing program, the laser test could be expanded to cover the space link. This is shown schematically by Figure 15. After completion of the servicing functions, the propulsion unit (PSRE) has sufficient performance to alter its orbital altitude to approximately 1480 km (800 nmi). Nodal regression will separate the orbits, and a test range of over 7400 km (4000 nmi) can be achieved.

These elements, for the most part, represent existing designs, if not existing equipment. The overall schedule for design, fabrication, and testing is shown in Figure 16, leading to a flight test in the first part of 1978. The schedule shown for the P72-2 vehicle is derived from current program experience and is reasonably representative of any hardware procurement cycle, given that the equipment has been previously qualified. The propulsion unit (PSRE) has also been developed but the avionics would require a new effort. Existing avionics, similar to that of the P 72-2 vehicle, would be adequate except for the rendezvous sensors. These have been identified as GFE from NASA, since this requirement already exists for the tug, although the time period has been advanced.

This leaves the major new development effort for the service unit itself. The design must necessarily be simple to be compatible with the other vehicles; hence, an 18-month development is not unrealistic. The major concern is for test and integration to assure that a flight qualified product is achieved; eight to 10 months have been allowed for this. The overall program plan requires approximately

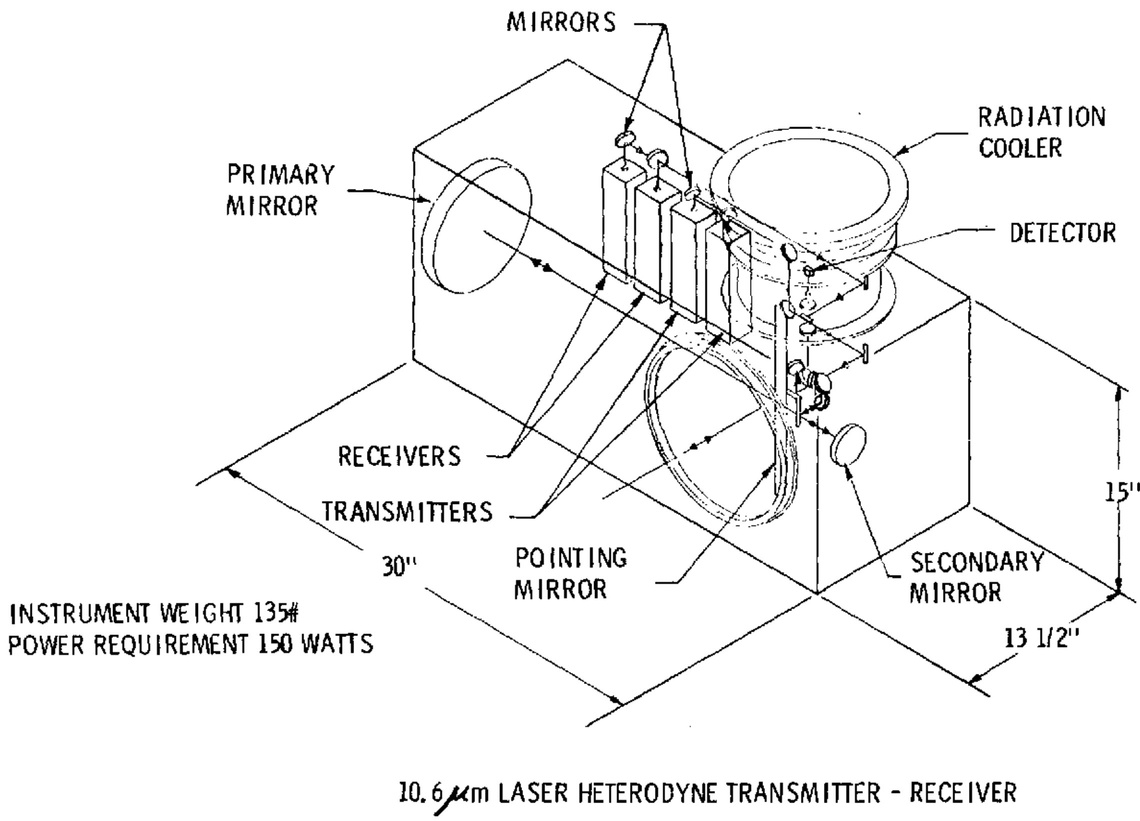


Figure 14. Laser Communication Experiment Package

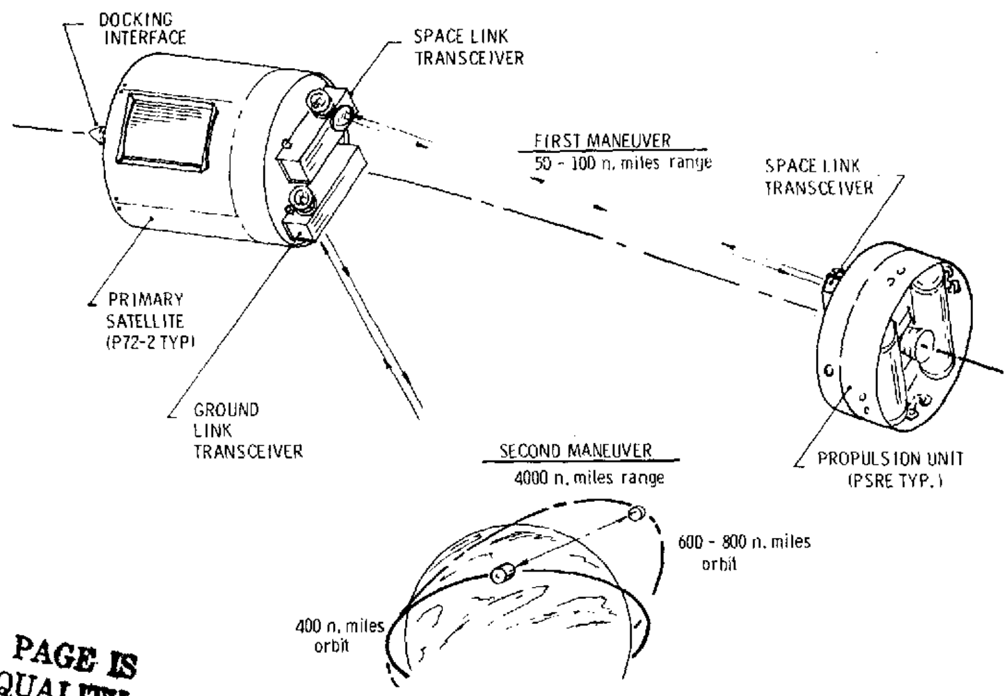
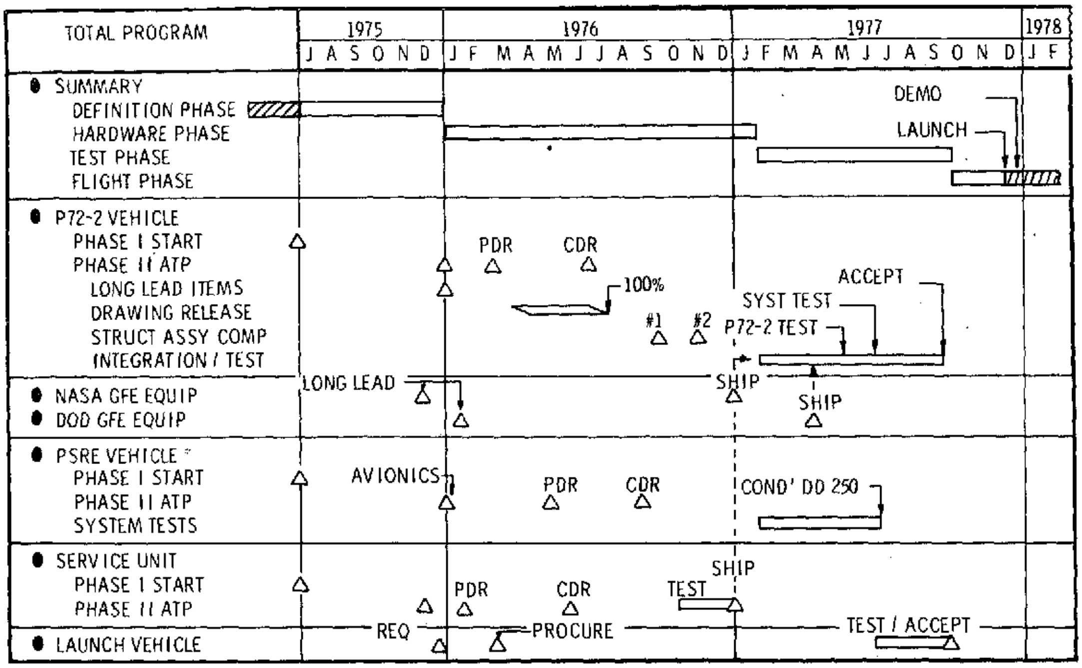


Figure 15. Laser Communication Test Concept



* POTENTIAL SPARES AVAILABILITY

Figure 16. Space Servicing Pilot Program Development Schedule

Table 2. Funding Requirements for Space Servicing Pilot Program

	PROGRAM FUNDING $M								
	FY 75		FY 76		FY 77		FY 78		TOTAL
	USAF	NASA	USAF	NASA	USAF	NASA	USAF	NASA	
1. MISSION SPECIFICATIONS									
MISSION REQ		0.100							
STP P.O. INTERFACE REQ	0.130								
NASA CENTERS SUPPORT	—	—							
2. HARDWARE DEFINITION PHASE									
P72-2 VEHICLE & INTEGRATION			1.2						
PSRE VEHICLE/AVIONICS				0.3					
SERVICE UNIT/SRU DESIGN *				0.8					
RENDEZVOUS SENSORS (TUG PROGRAM)				-					
INTEGRATION SUPPORT			0.6	0.6					
3. HARDWARE PROCUREMENT									
LAUNCH SERVICES			0.5		2.0 **	0.5	2.0		
P72-2 VEHICLE					4.0	2.0			
PSRE VEHICLE						1.0			
SERVICE UNIT						1.2			
INTEGRATION SUPPORT					0.8	0.6			
EXPERIMENTS					-	-	-		
4. INTEGRATED TEST PROGRAM									
SYSTEMS TESTS							1.0	1.0	
FLIGHT TEST							1.0	2.0	
DATA ANALYSIS/SUPPORT							0.5	2.0	
TOTAL NASA		0.10		1.7		5.3		5.0	12.1
TOTAL USAF	0.13		2.3		6.8		4.5		13.73

* POTENTIAL SUPPORT FROM SPAR
**ADDITIONAL FUNDS AVAILABLE UNDER LINE

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30 months of effort.

It has been assumed that development of the primary satellite (P 72-2 vs alternatives) would be the responsibility of the USAF STP Office because this vehicle must be compatible with other USAF experiments and fit within budget allocations. Modifications to this vehicle to support space servicing would be funded by NASA. The propulsion unit with avionics and the docking and servicing mechanisms would also be a NASA responsibility. Integration, testing and launch costs would be shared. A complete breakdown of total costs based upon these ground rules is provided in Table 2. These costs represent the equipment as it exists today with some slight margins to accommodate a rise in costs in the future. The estimated cost sharing is also shown. The total program cost is estimated to be approximately $26 million.

Several points need to be made regarding this table. Perhaps the most important is that, although these costs represent contractor inputs and are consistent with previous program experience, there is still an inherent uncertainty due to the current wave of inflation. In addition, integration efforts are not definable at this time and tend to cloud the picture. Therefore, the funding plan has been organized such that the major costs are not incurred until after PDR or CDR for most of the hardware elements. Funding in FY 75 establishes mission requirements. Funding in FY 76 establishes the design approach, the DoD experiment support requirements, the interface specifications, and the test requirements. At this time, it is possible to firm up the remaining costs for FY 77 and FY 78 and to select the remaining course of action. By the end of FY 76, it will also be possible to determine the degree to which various payload offices are willing to support the pilot program efforts. The investment to this point is between 10 and 15 percent of the effort.

In addition, it has been determined that spare PSRE vehicles may exist in the USAF inventory. It appears very likely that one or two units could be released to NASA without cost for this effort. Even in the event this does not occur, a late input gives the current cost of the PSRE at $500 thousand instead of $1 million as shown in the table. Also, certain avionic components have been given to NASA (Reference 6) from the recently cancelled Earth Limb Measurement Satellite Program (ELMS). These components could be employed for either the PSRE avionics wafer or to reduce the cost of the P 72-2 primary satellite. The cost savings accrued by this action is estimated to be between one and two million dollars. If all of the equipment requested had been transferred to NASA, the cost savings in hardware alone would exceed 2.5 million dollars with additional manpower support savings.

In summary, this option has several features which support the argument to initiate the effort immediately at a minimum of risk relative to a full commitment of funds.

a. Timing is favorable to provide inputs to the major servicing effort.

b. Existing hardware can be employed to a large extent.

c. Commitment of funds is low until final cost and design data is available.

d. Spare PSREs may be available to reduce costs from those shown.

e. Spare components have already been transferred to NASA providing additional cost savings.

4.3 ETR OPTION

The ETR option shares many of the same advantages; however, the total cost to NASA will be somewhat higher. A schematic of this option is shown in Figure 17. A serviceable payload is deployed in the transtage parking orbit as a piggyback payload on a programmed USAF mission. A subsequent flight after six months of operation would be performed using a Delta vehicle. The propulsion unit (PSRE), a service unit, and replacement modules would be deployed and servicing performed. This option has the additional advantages of more complete rendezvous operations and a demonstration of extending the operational life of a payload.

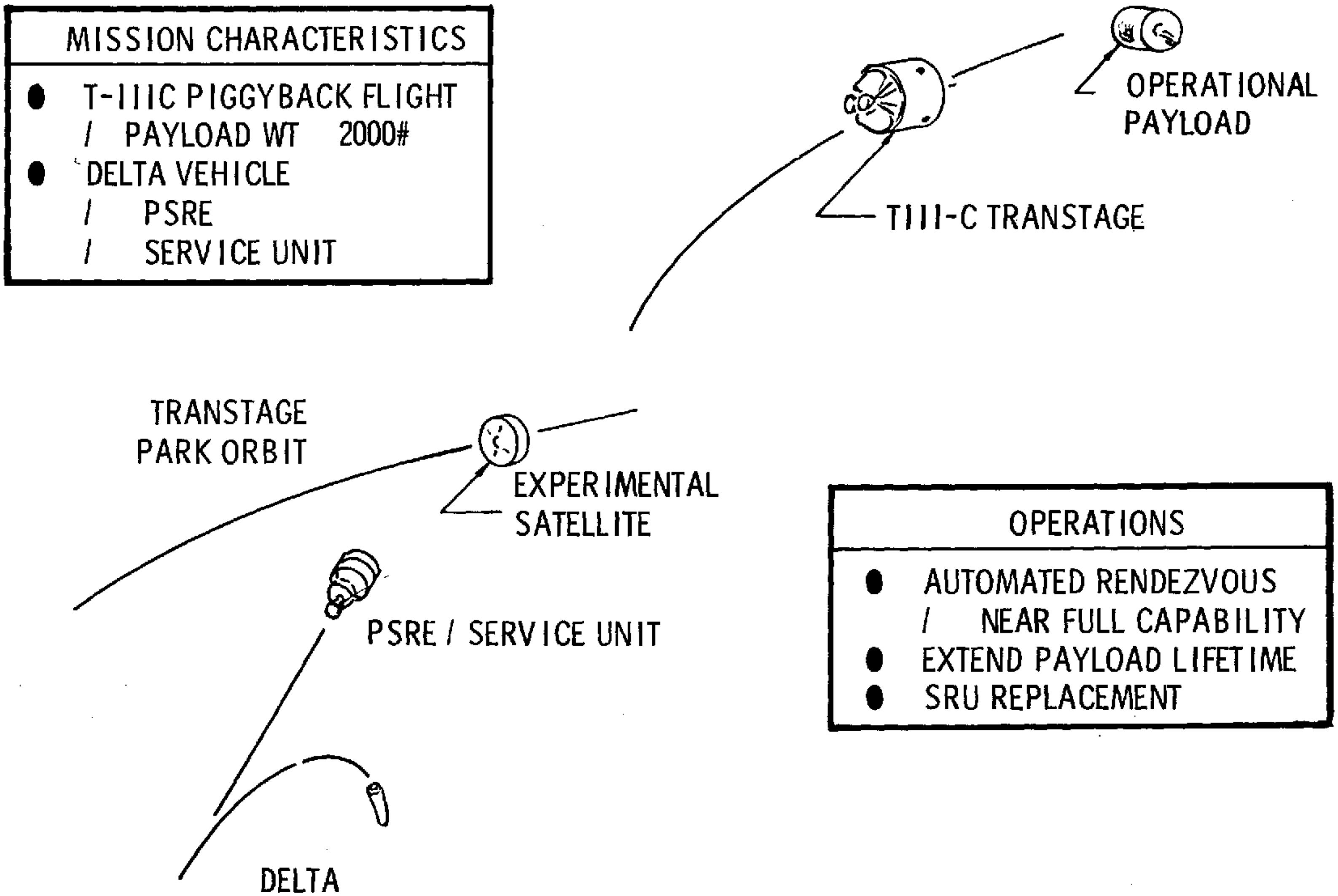

Figure 17. ETR Pilot Program Option

Again existing equipment would be employed wherever possible and the same comments apply for the PSRE and ELMs components. Details of the remaining equipment are shown in Figure 18. A preliminary design has been performed by the Titan III contractor indicating that a 48-inch wafer section can be inserted at the interface of the Transtage. A version of a standard space vehicle (SSV), currently under study at SAMSO, could be modified for servicing and ejected as shown. This satellite would conduct STP experiments just as the WTR option, although the SSV satellite would be slightly smaller to meet the constraints of the Titan III wafer. The size restriction, however, should not preclude performing the recommended laser communication experiment, although this subject requires more effort. There may be alternatives as yet not explored.

The total cost of this option is estimated to be approximately $28 million as shown in Table 3. The service unit, serviceable satellite, and Titan III wafer are new design items. In addition, rendezvous avionics has been incorporated into the cost of the service vehicle system, rather than regarding this as a GFE item. This option is under consideration by SAMSO relative to their degree of participation, but it appears that NASA would be required to absorb 70% or more of the program. This cost must be viewed in light of the increased benefits derived from this option, which are the full rendezvous and actual lifetime extension of an operating satellite. The development schedule would be very similar to that previously shown for the first option.

4.4 COMPARISONS

There are no severe hardware problems apparent in either option. Either approach offers the capability to initiate the developmental process to eventually arrive at a mature space servicing concept. In addition, it is also possible to acquire an interim servicing capability using the same components employed for the pilot program. This interim servicing capability would fulfill an important role in bringing space servic-

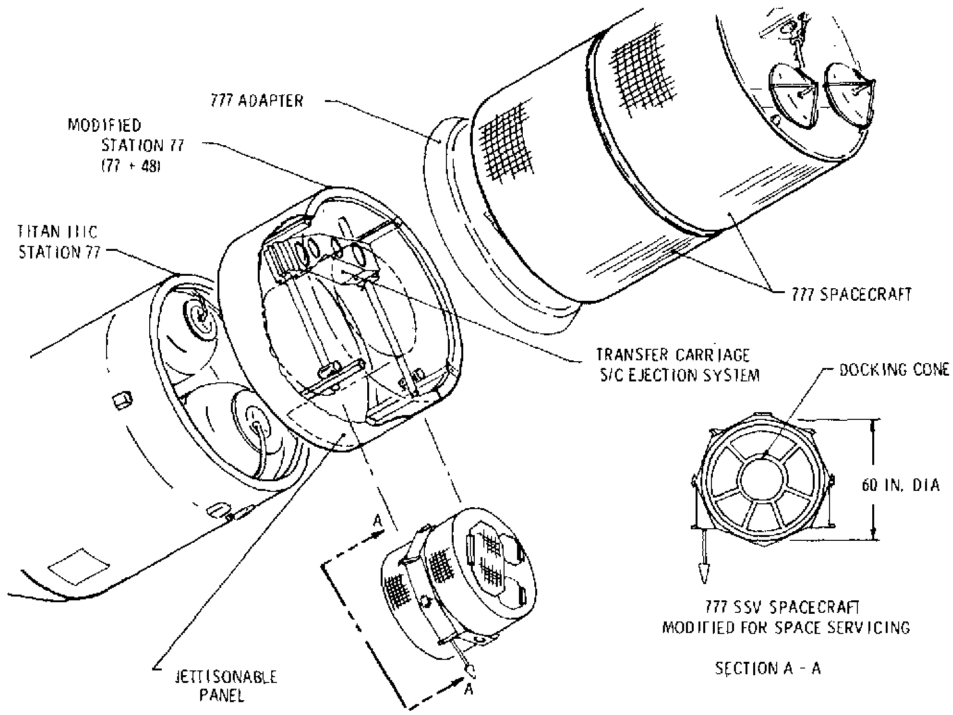

Figure 18. ETR Option Hardware Elements

Table 3. Cost Estimate of ETR Option

HARDWARE ELEMENT	COST $M
• SERVICE VEHICLE	10.0
/ PROPULSION	
/ ASTRIONICS	
/ SERVICE UNIT	
• SERVICEABLE SATELLITE	7.0
• TIIIC - WAFER STRUCTURE	2.0
• INTEGRATION	2.0
• LAUNCH COST (DELTA)	6.5
• PHASE I DEFINITION	1.0
TOTAL	28.5

ing to an operational reality for two reasons. Payloads to be deployed prior to 1984 could be designed for servicing, thereby providing a progressive buildup of programs that could take advantage of the full capability Tug when it becomes available. Many of these payloads may not require servicing prior to the Tug IOC but a capability for space servicing should be incorporated. Otherwise, the process of converting payload designs to serviceable concepts will be delayed for years.

An equally cogent reason is that providing this support capability will exercise the full spectrum of operational procedures, including plane change maneuvers, servicing time lines, and retrieval by the Shuttle. This effort, besides providing a service to operational payloads, will provide the needed experience to make full utilization of the Tug when operational. The interim capability becomes the training ground in this evolutionary process.

Figure 19 provides a comparison of interim and full space servicing configurations. The propulsion unit (PSRE) employed for the pilot program can be employed for interim servicing as well. The performance capability of the interim upper stage (IUS) is more than adequate to provide this capability and may in fact be able to service more than one payload on a given flight. The service unit itself should be more advanced than that employed in the pilot program, taking advantage of that experience and reflecting the character of the payloads to be serviced. Interim servicing may not be economical by itself, but it provides the foundation to achieve a high yield early in the Tug operational time period.

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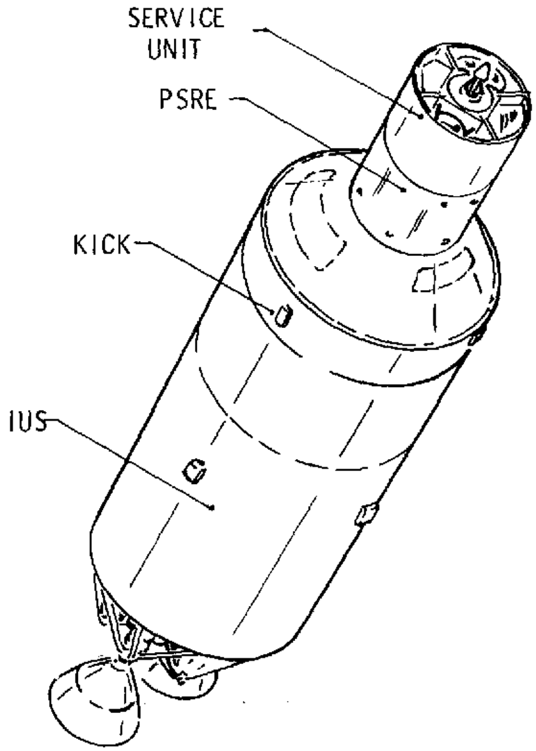
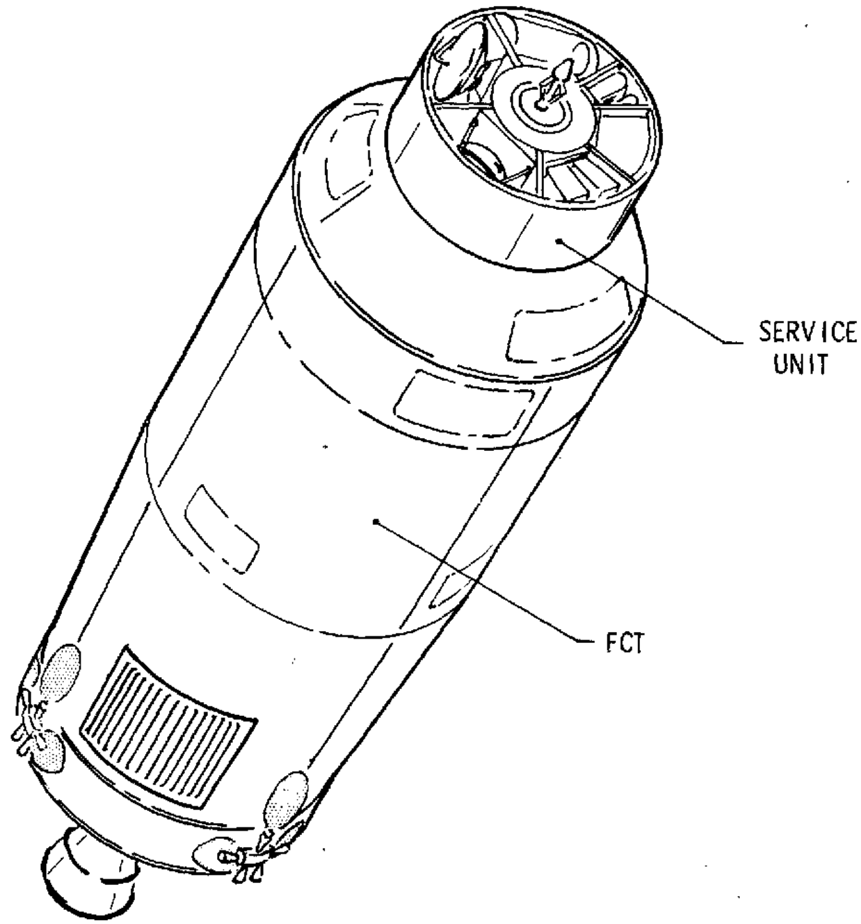


- INTERIM SERVICING
  / DEVELOP OPERATIONAL CAPABILITY
    - AUTOMATED RENDEZVOUS
    - GEOSYNC PHASING
  / PROVIDES NECESSARY SUPPORT TO PAYLOADS DEPLOYED PRIOR TO IOC OF FCT



- FULL CAPABILITY SERVICING
  / 2ND GENERATION SERVICE UNIT
  / MULTI - SERVICING
  / SPACE BASED OPTION

Figure 19. Interim and Full Capability Servicing Concepts

5. CONCLUSIONS AND RECOMMENDATIONS

The process of developing any new operational concept, such as space servicing, will inherently require many years of dedicated effort. However, the results of this analysis indicate that this dedication will provide substantial benefits in terms of future space flight operations. It also indicates that the shift from current expendable payload concepts to space servicing will probably follow an evolutionary process and that this process must be initiated in the very near future if progress is to be seen in the 1980 - 1990 time period. Any substantial delay sustains a significant loss in benefits which is irreversable. In consequence, it is recommended that NASA management take immediate action to develop a firm plan of approach leading to an operational capability in the early 1980 time frame.

Several options may be available for management consideration. The pilot program proposed in this report was prepared for the specific purpose of determining if this approach represented a viable alternative to those options which may already be under consideration. It is felt that this concept not only satisfies the need for early payload user interaction but also provides a rational approach to evolve to a full capability when the TUG becomes operational.

The results provided in this report indicate that on a conservative basis over $200 million can be saved over an 11-yr period by employing space servicing. Further optimization of the payload designs and operational procedures should provide a substantial improvement in these benefits. These savings can be applied to the developmental effort required to achieve this capability. Although no firm estimate of DDT&E costs can be made, it is apparent that even these conservative returns will be sufficient to justify the effort. However, experience has shown that any major change of course such as this must be an evolutionary process, allowing confidence to be developed prior to a full commitment of efforts. Experience has also shown that this process will require several years to achieve an operational capability and that two or more design generations will be required to reach maturity.

Payload programs will not automatically accept a new operational concept. The economic benefits must be proven and applied against the anticipated risk that is inherent in any new process. This requires a demonstration effort, involving payload users to overcome the inertia involved with current practices. Such a program must also provide the first step to broader applications and assure that the initial investment has a relatively high chance of subsequent benefits.

A program plan has been presented which accomplishes these objectives with a relatively low investment. Two options have been developed which have application to both NASA and USAF future program efforts and, therefore, through shared funding provide a capability which probably could not be achieved otherwise. Although specific design approaches have been shown, it is not the intent to specify a preferred approach at this point in time. It is important to note, however, that existing equipment can be employed to a very large extent, minimizing the risk of new developmental items. It is also important to recognize that this program has the potential to evolve directly into an interim servicing capability, providing not only fundamental design requirements but also hardware elements.

Finally, a point should be made regarding funding levels. The total effort is estimated to cost approximately $25 million shared by NASA and the USAF. Full commitment to these funds is not required until firm design approaches and cost data are available from contractor efforts. An initial effort is recommended in the last half of FY 75 to establish mission requirements and design specifications and to develop the procurement package for FY 76. The funding levels for FY 76 require approximately $2 million each from NASA and the USAF. However, only about one-half of this is required to reach the critical design review (CDR) on all development items. At that point in time, the design will be firm, the interface specifications will be firm, and firm costing can be committed. The decision can then be made to proceed or reprogram as necessary. Hence, the commitment up to this time is little more than the current study efforts investigating various space servicing concepts.

Experience has shown that study results alone will not alter the course of current payload program efforts. Operational procedures must be demonstrated and the associated risk of development must be overcome. This is the first step in developing confidence in a new operational concept which should provide benefits to the payload user as well as to the Space Transportation System.

REFERENCES

1. The 1973 NASA Payload Model; Space Opportunities (1973-1991), NASA (October 1973).
2. Operations Analysis (Study 2.1), ATR-74(7341)-3, Payload Designs for Space Servicing, The Aerospace Corporation, El Segundo, California (30 June 1974).
3. Operations Analysis (Study 2.1), ATR-74(7341)-3, ADD., Payload Designs for Space Servicing Addendum, The Aerospace Corporation, El Segundo, California (30 September 1974).
4. Aerospace IOC 73-2810K-125 (7 Dec 1973), from L. L. Schilb to G. M. Forslund, Subject: Performance Data Supplied to Upper Stage Assessment
5. Baseline Space Tug Configuration Definition, NASA/MSFC 15 July 1974).
6. DD Form 1149 Requesting Transfer of specific avionic equipment from USAF SAMSO to NASA Goddard Space Flight Center (December 1974)

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